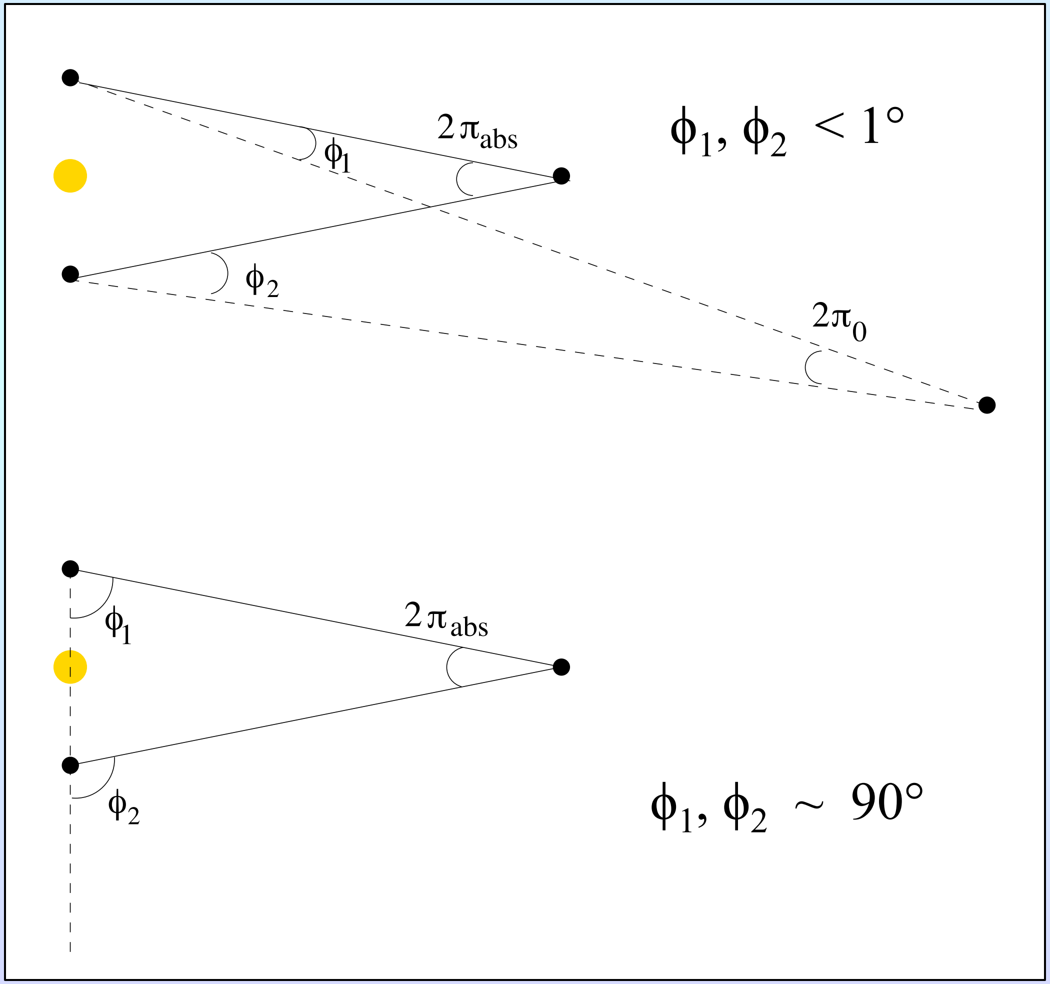
Numbers to Keep in Mind

- $R_\odot \sim 7 \times 10^{10}$ cm
- $M_\odot \sim 2 \times 10^{33}$ gm
- $L_\odot \sim 4 \times 10^{33}$ ergs/sec
- $T_{\mathrm{eff}}\odot \sim 5780°$
- $X \sim 0.75$
- $Y \sim 0.23$
- $Z \sim 0.02$
- $\mathrm{M}_\odot$(bol)= +4.74
- $\rho_\odot \sim 1.4$ gm/cm^3
- $\mathrm{T}_\mathrm{c}\odot \sim 15{,}000{,}000°$ K
- $\rho_\mathrm{c}\odot \sim 1400$ gm/cm^3

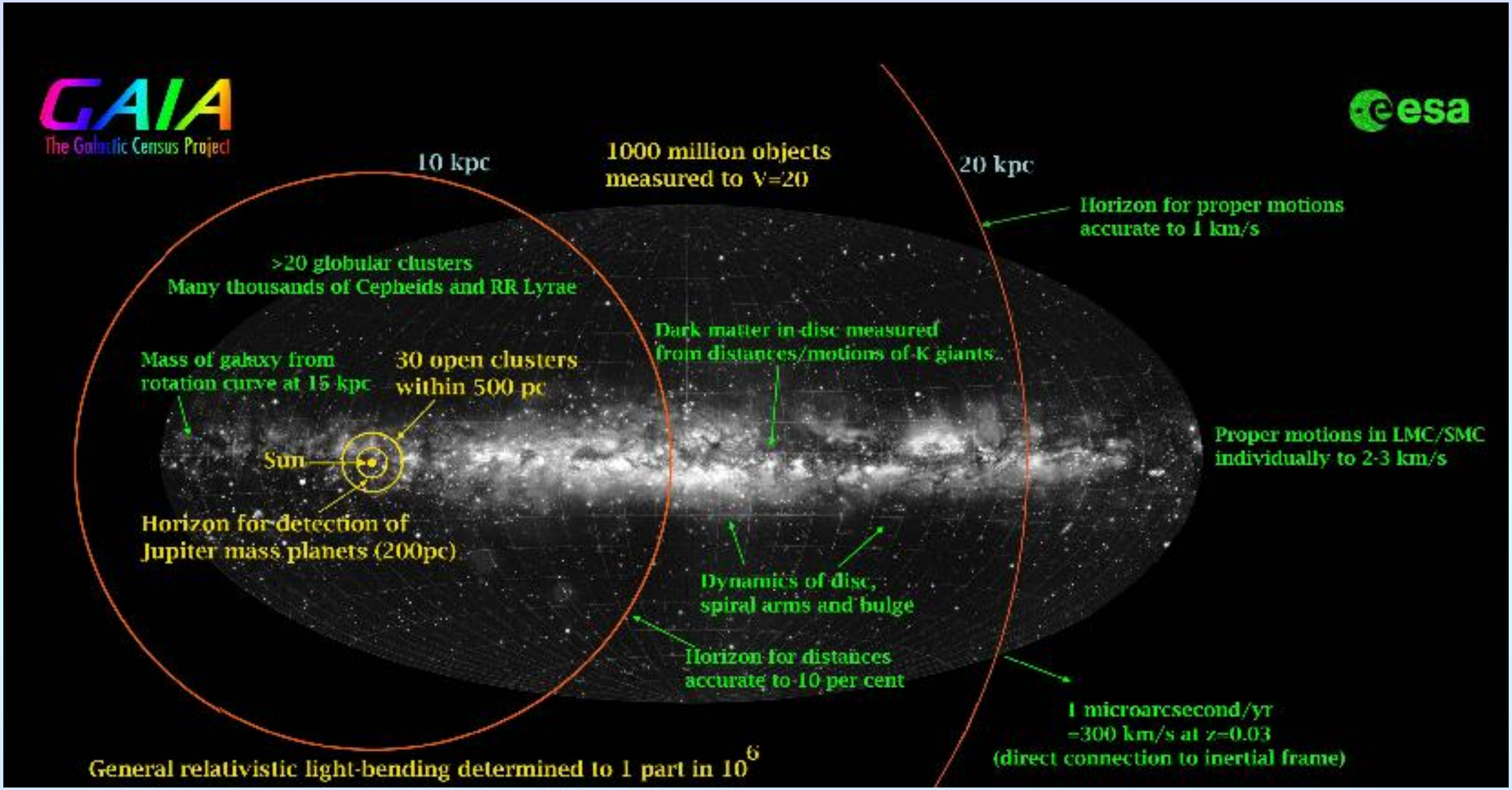
Stellar Luminosities from Parallax

Stellar luminosities come from distance measurements. The best way to perform such measurements is through parallax.

Ground-based measurements produce relative parallaxes; Space-based observations can produce absolute parallaxes by referring to stars ~90° away.



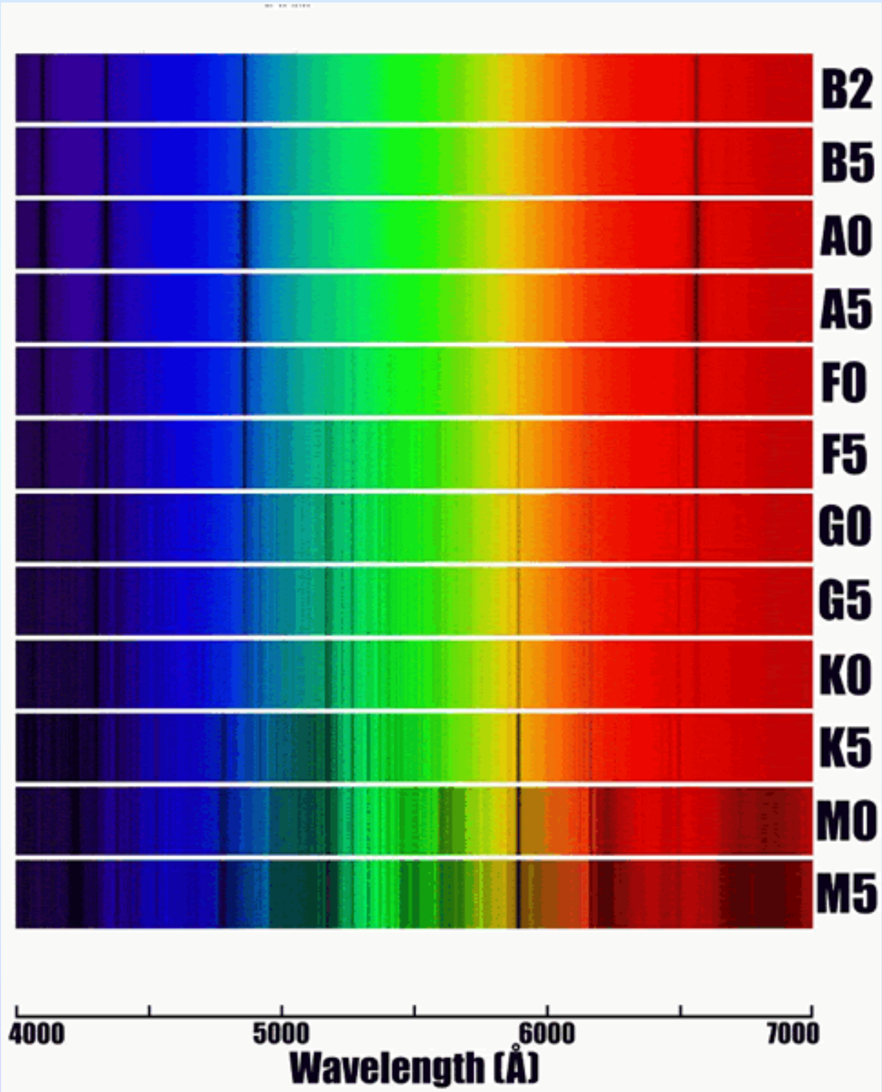
GAIA Survey

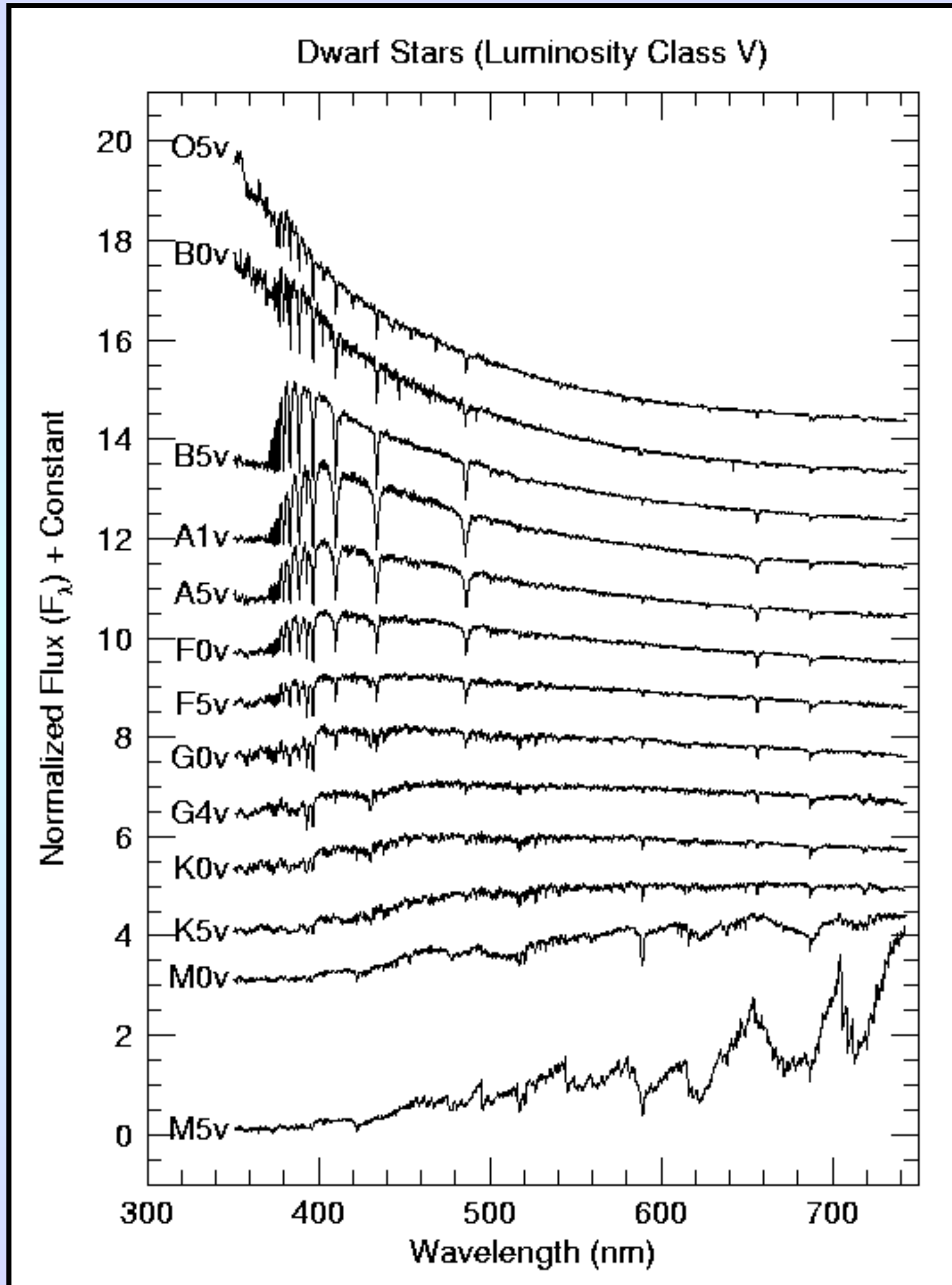


V	10	11	12	13	14	15	16	17	18	19	20	21
σ (μ arcsec)	4.0	4.0	4.2	6.0	9.1	14.3	23.1	38.8	69.7	138	312	1786

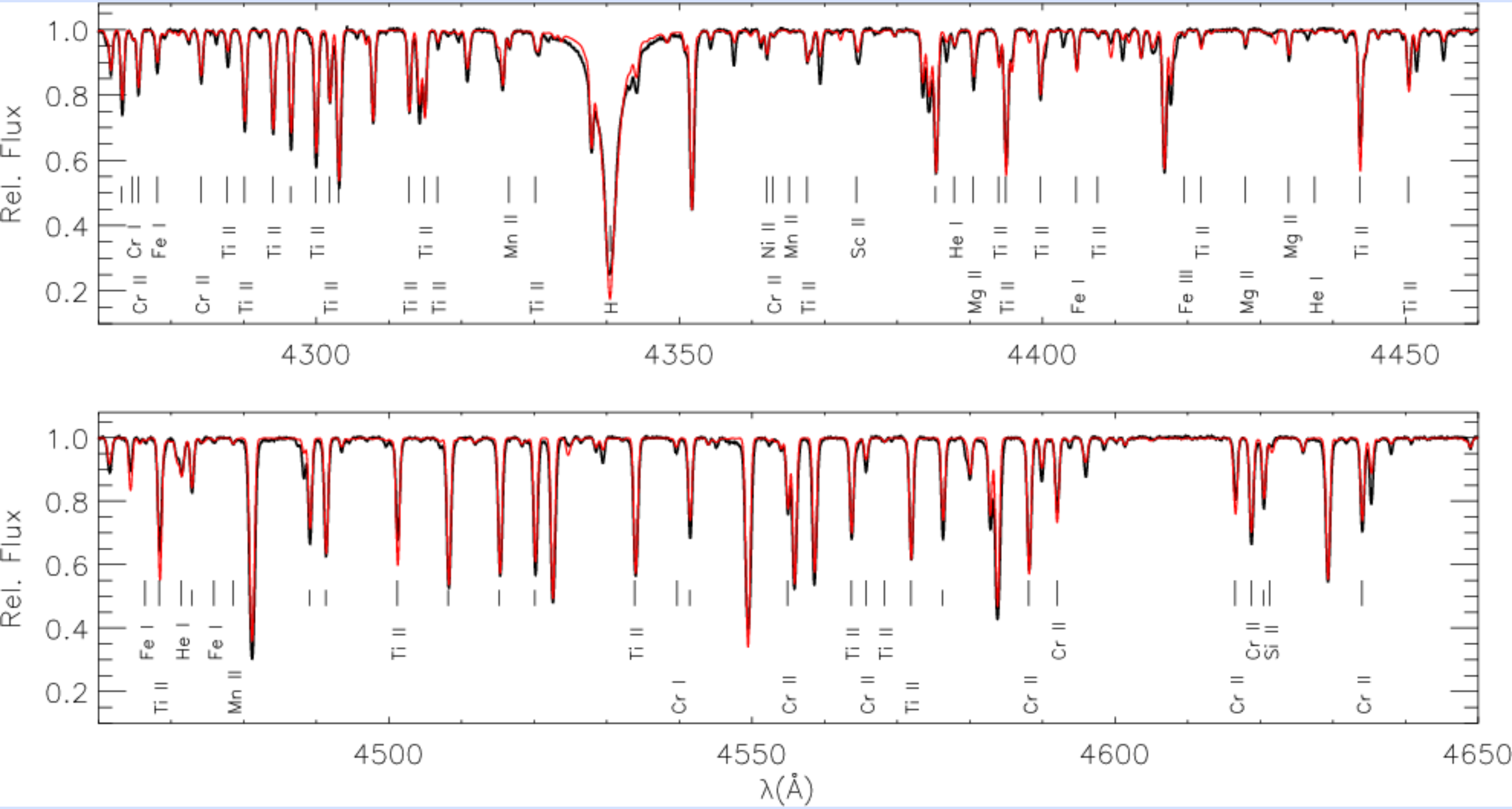
Gaia DR2 was last year; there will be 5 data releases

Stellar Temperatures come from spectra

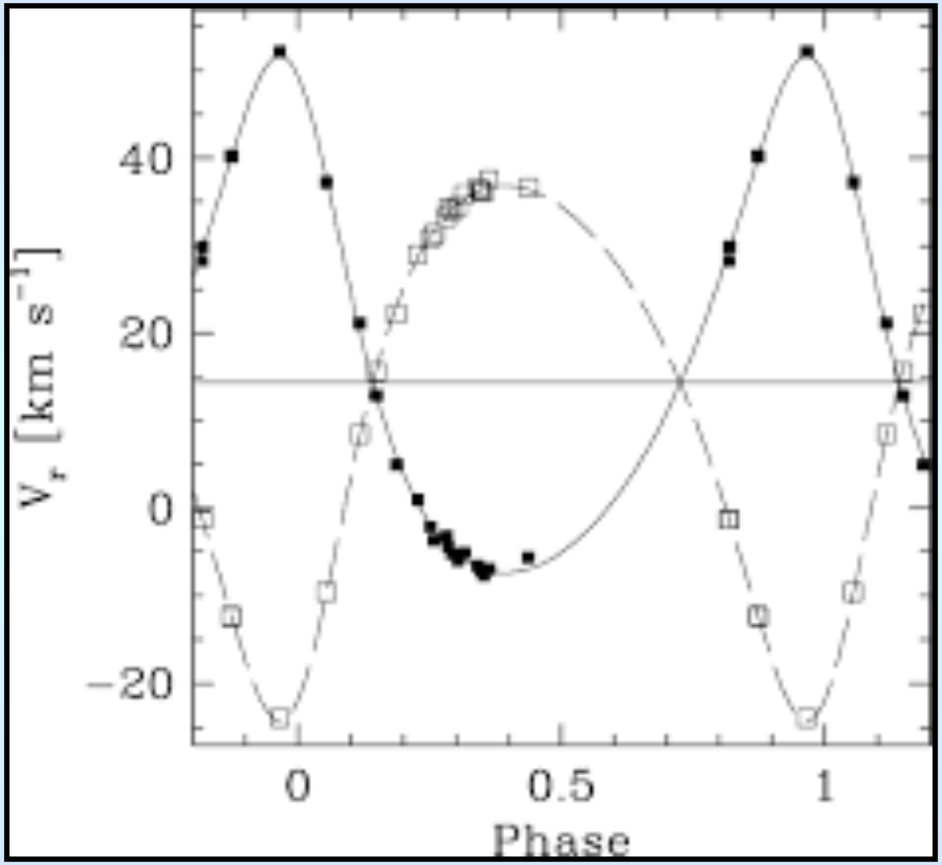


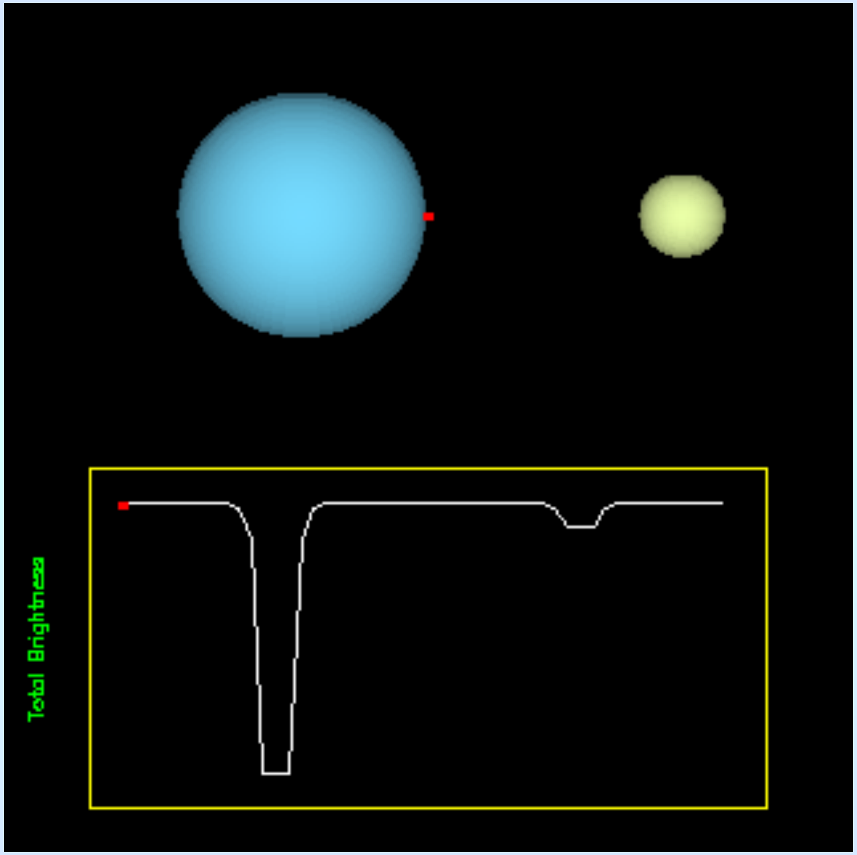


Stellar Abundances also come from spectra



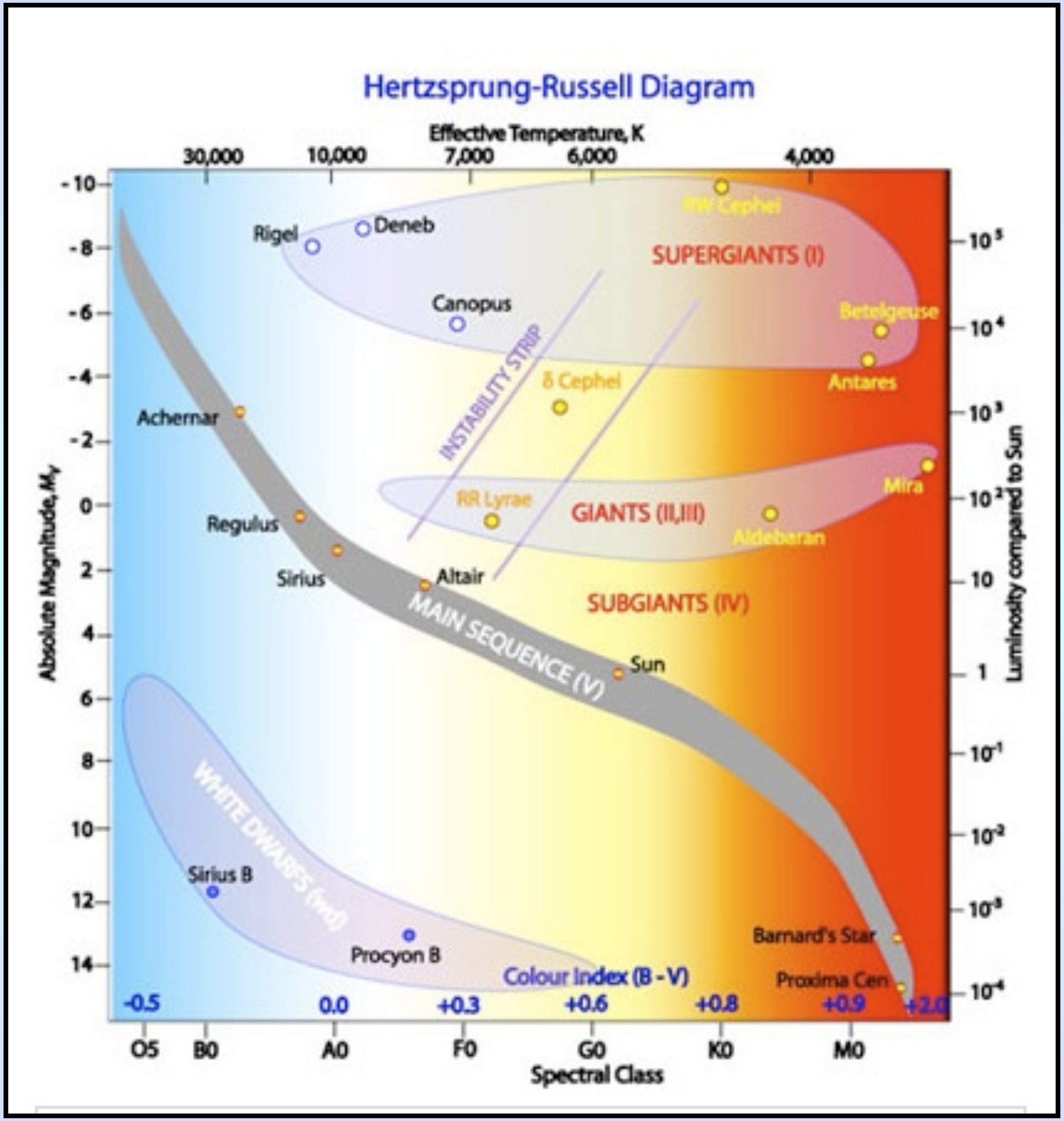
Stellar Sizes and Mass primarily come from Binary Stars





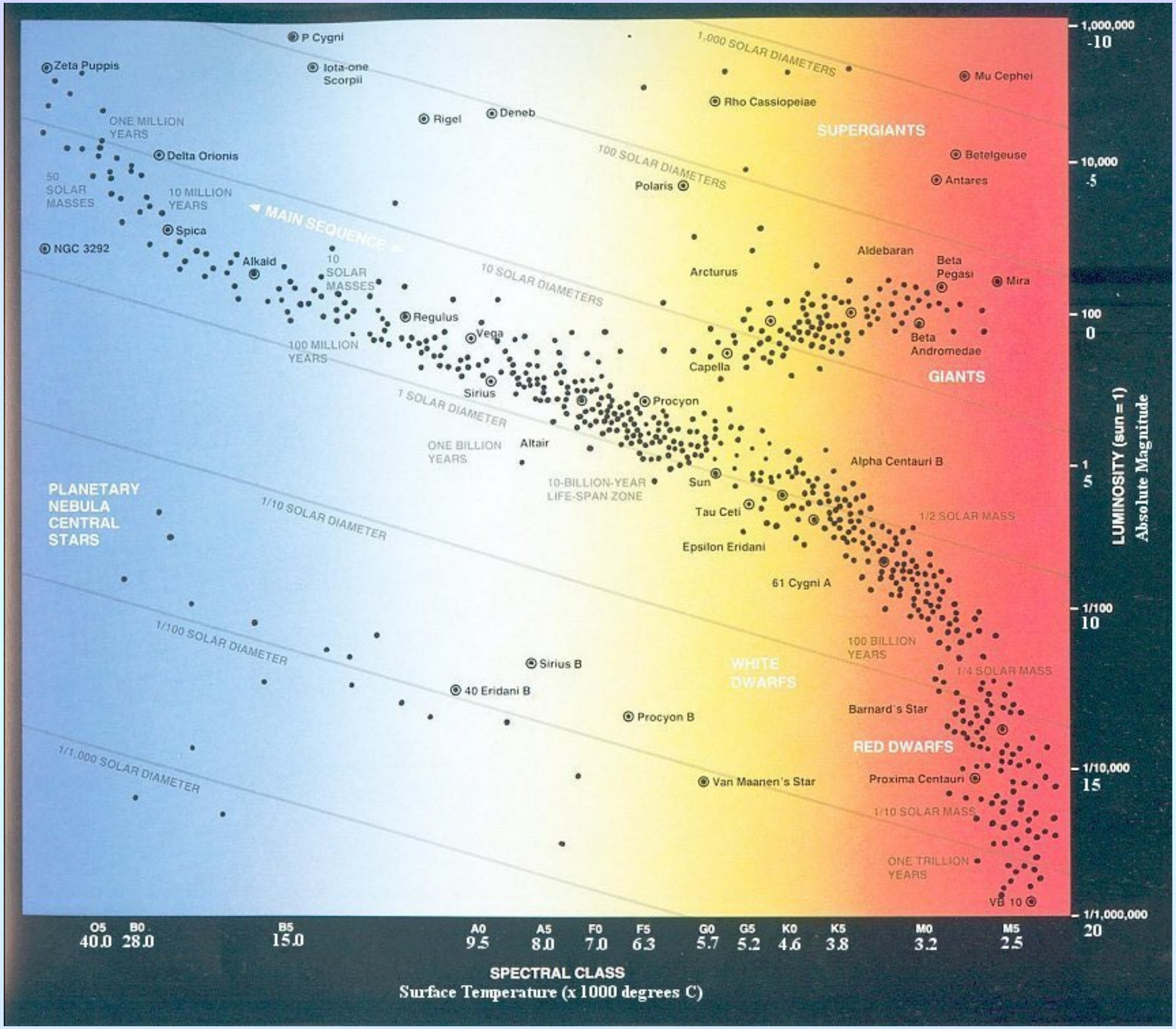
The HR Diagram

Most (>90%) stars lie on the "main sequence". A few stars are cool and extremely bright, so, by $L = 4 \pi R^2 \sigma T^4$, they must be extremely large. A few stars are hot, but extremely faint, so they must be very small.



The HR Diagram

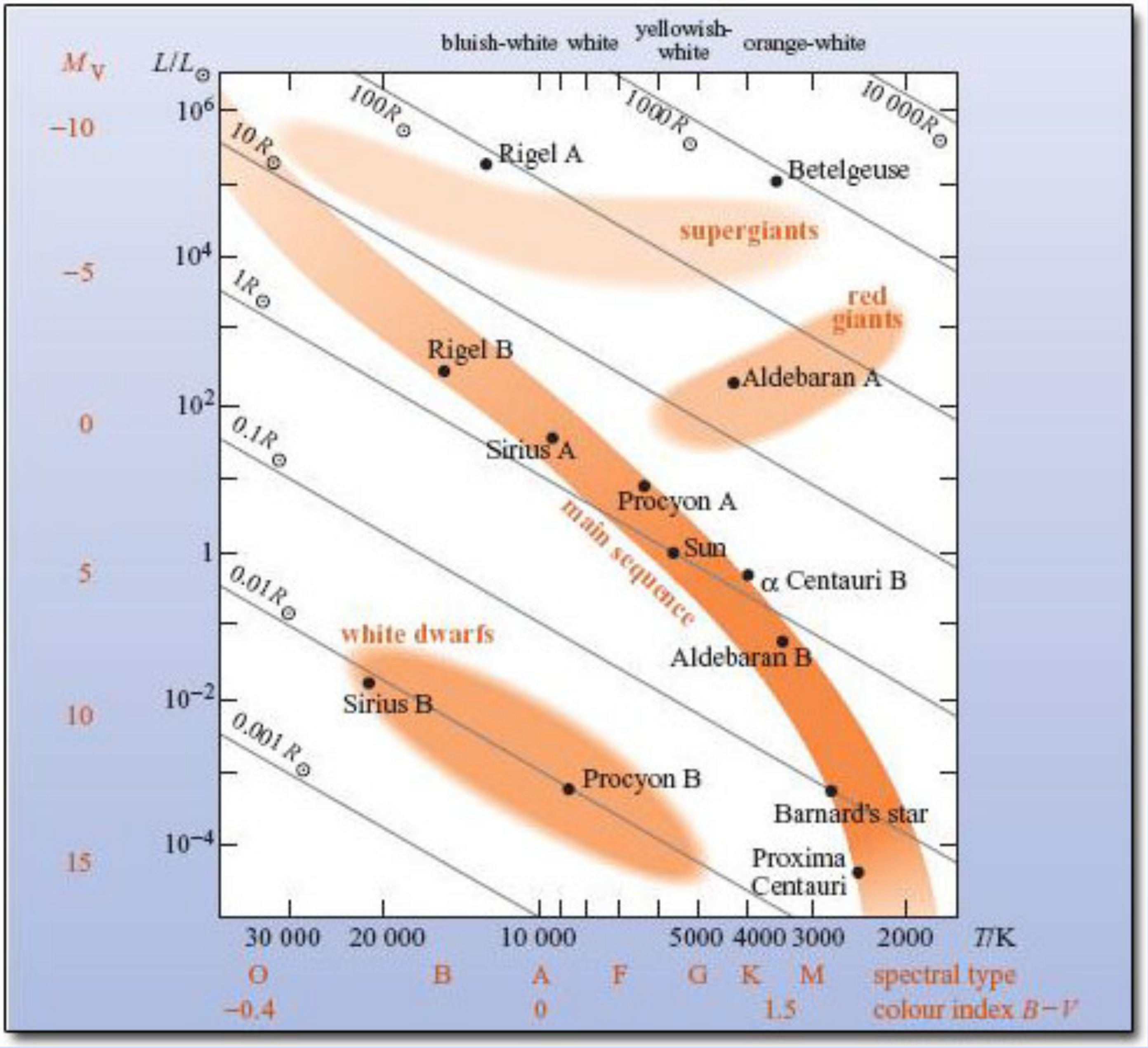
Most (>90%) stars lie on the "main sequence". (But most stars you know are giant stars.) You can see them much further away!



$$f \propto \frac{L}{d^2} \quad \Rightarrow \quad L \propto d^2$$

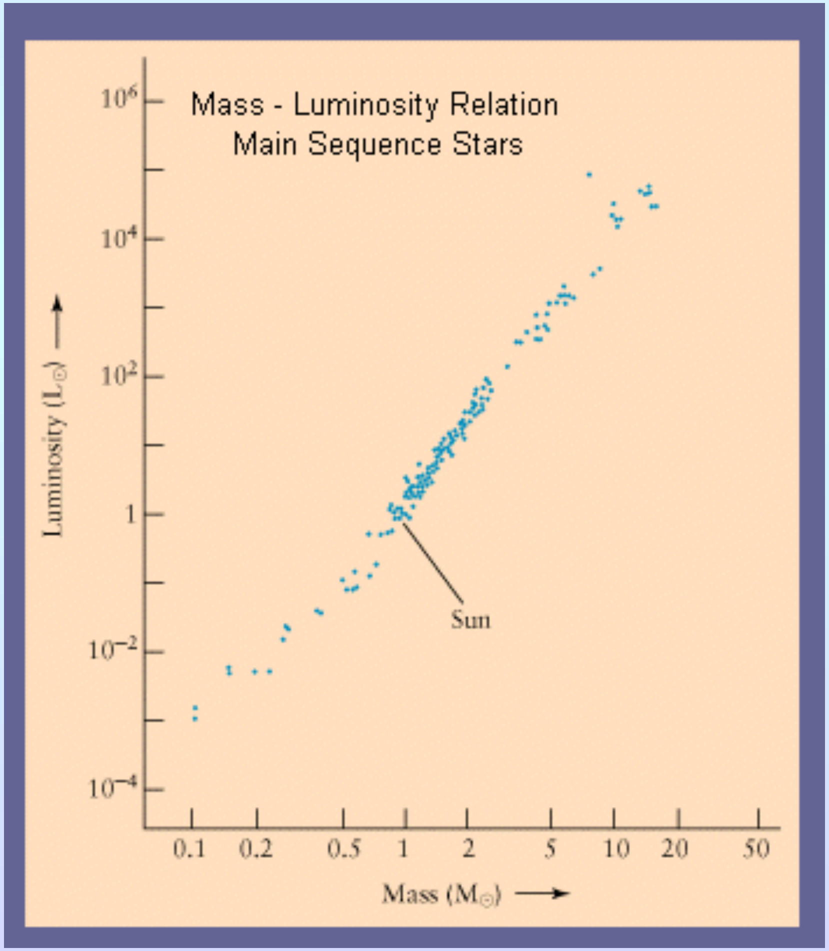
$$N_{\mathrm{obj}} \propto V \propto d^3 \quad \Rightarrow \quad N_{\mathrm{obj}} \propto L^{3/2}$$

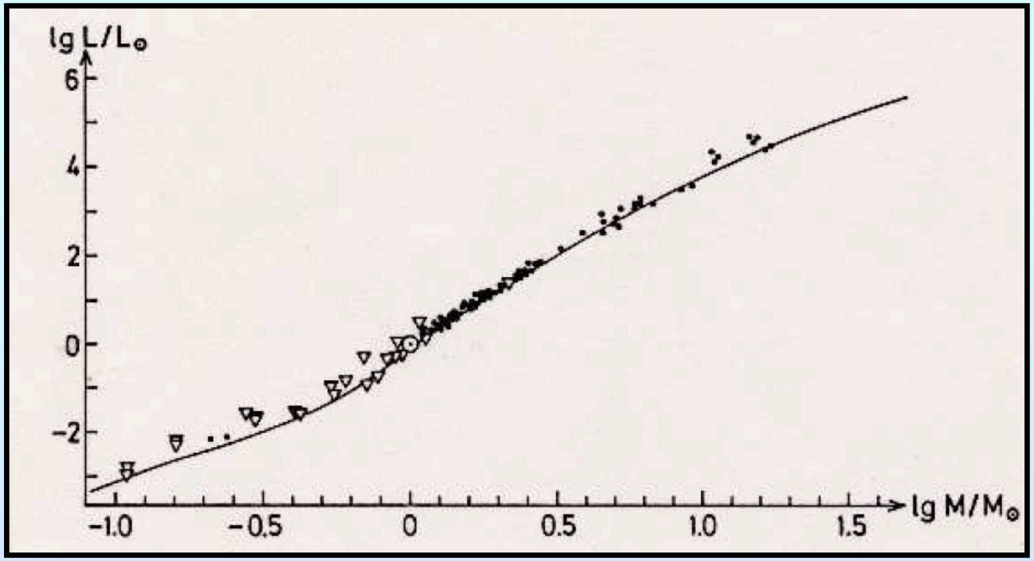
The HR Diagram with Iso-Radius Lines



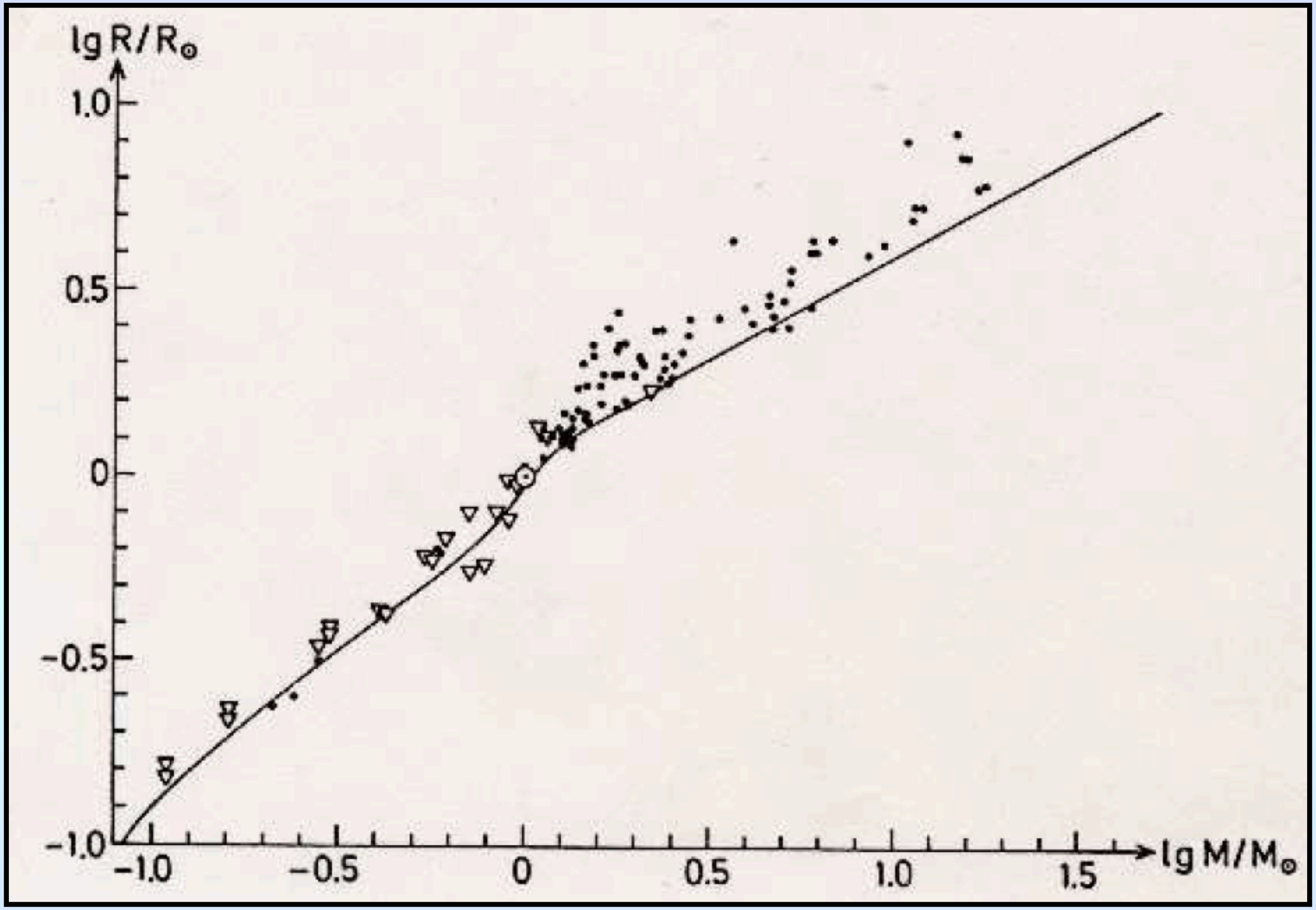
Stellar Masses and the Main Sequence

Measurements of main-sequence stars demonstrate that there is a mass-luminosity relationship, i.e., $L \propto M^{\eta}$. For $M > 1\ M_{\odot}$ $\eta \sim 3.88$, while at lower masses, the relation flattens out. A good rule-of-thumb is $L \propto M^{\eta}$, with $\eta \sim 3.5$.



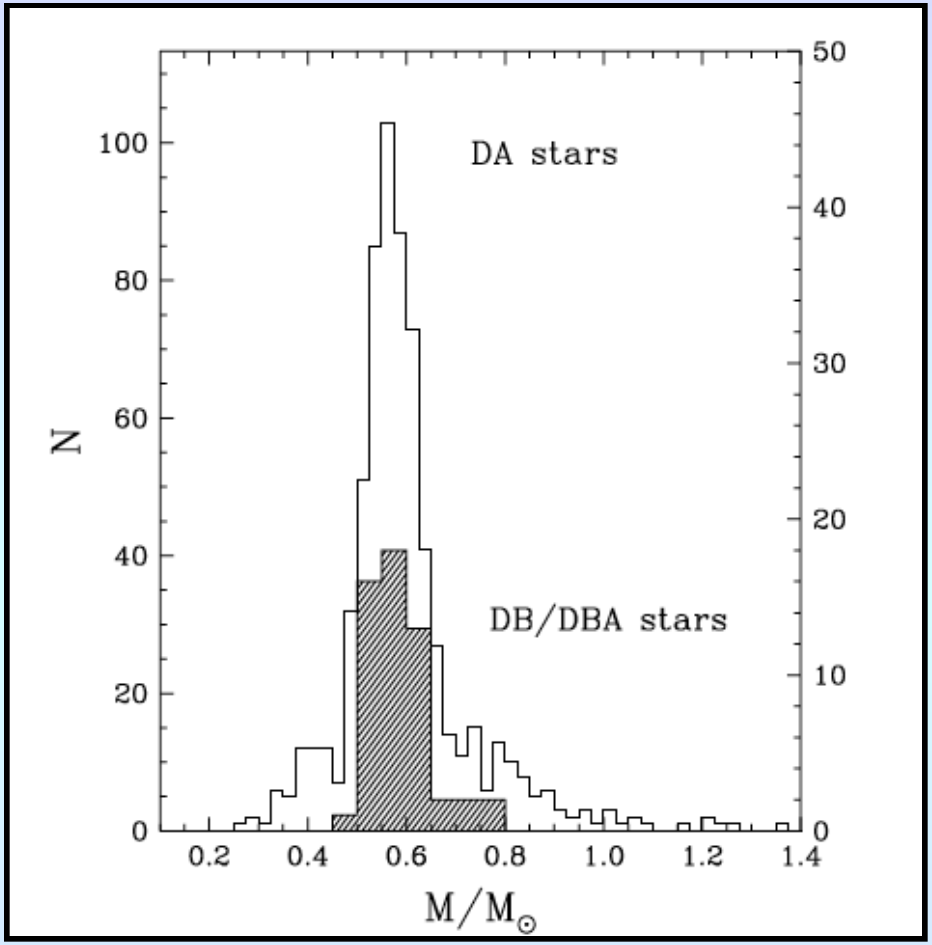


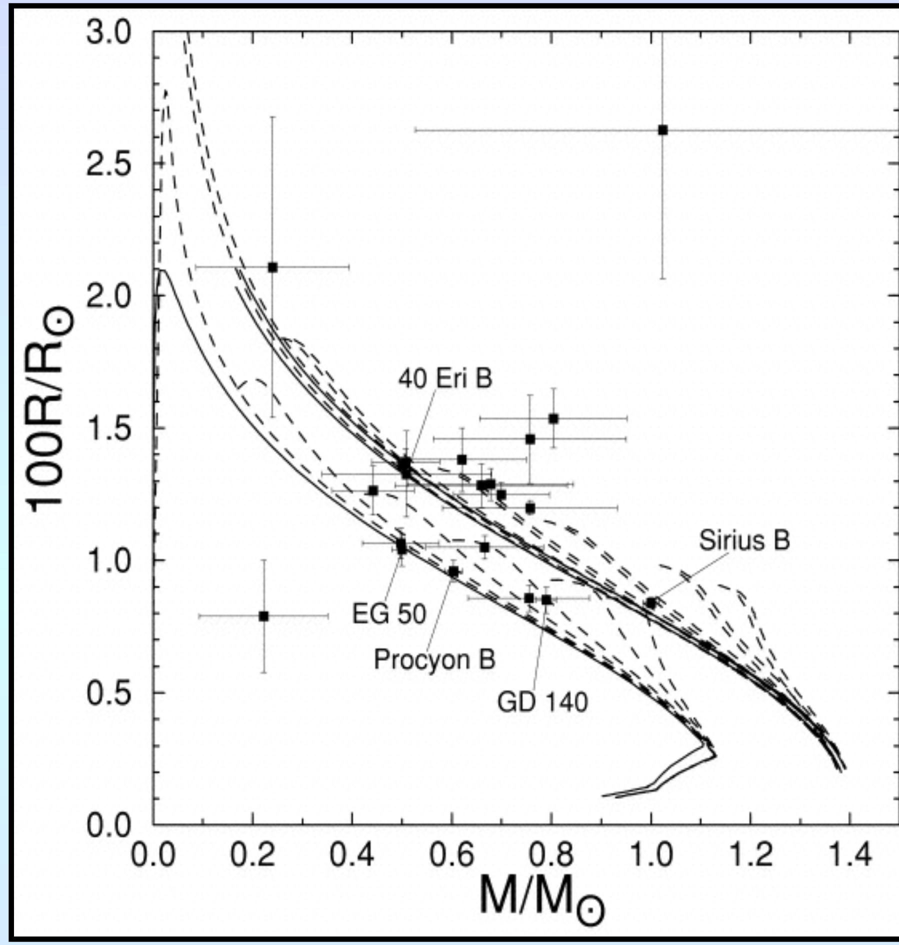
Main Sequence Mass-Radius Relation



There is also a mass-radius relation for main-sequence stars. When parameterized via a power law, $R \propto M^{\xi}$, $\xi \sim 0.57$ for $M > 1\ M_\odot$, and $\xi \sim 0.8$ for $M < 1\ M_\odot$.

Stellar Masses for White Dwarfs





The masses of white dwarf stars are all less than 1.4 $M_\odot$. Most are ~ 0.59 $M_\odot$.

There is also an inverse mass-radius relation for white dwarfs. The simple theory says $M \propto R^{\alpha}$, with $\alpha = -1/3$.

Ages (in clusters) from Main Sequence Turnoff

Finally, we know the ages of stars in clusters from simple energy production arguments:

$$\tau \propto \frac{M}{L} \propto \frac{M}{M^{\alpha}} \propto M^{1-\alpha} \propto M^{-2.5}$$